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Integration of biofertilizers with in-organic fertilizers and zinc for growth, yeild and biochemical parameters of sweet corn

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Abstract
A field experiment was carried out during early zaid season 2018 at the research field, department of biological sciences, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad. To investigate the effect of "Integration of biofertilizers with inorganic fertilizers and zinc for growth, yield and biochemical parameters of sweet corn (*Zea mays* L. *saccharata*)". The experiment was laid out randomized block design with twelve treatments and three replications. With the aim to increase the growth, yield attributes and nutrient value of sweet corn by using different biofertilizers with chemical fertilizers and zinc. The variety USM. Sugar gold was used as experimental material and treatments consisted of various treatments of biofertilizers NFB (*Azotobacter chroococcum),* PSB *(Bacillus megaterium),* and KMB (*Bacillus mucilaginosus*) with inorganic fertilizers and zinc. Application of biofertilizers either single or combination (seed inoculation with soil application) with inorganic fertilizers and zinc caused considerable increase in plant height, number of leaves, days to tasseling and silking, number of per plant, cob length and diameter with and without husk (cm), green cob yield per plot, green fodder yield per plot, total chlorophyll content (mg/g FW), protein content (%), carbohydrate content (%) and benefit cost ratio. Biofertilizers significantly increased yield and yield attributing characters. The best treatment identified was based on the mean performance the treatment 11 NFB (*Azotobacter chroccocum)* + PSB (*Bacillus megaterium*) + KMB (*Frateuria aurantia*) seed inoculation with soil application + Zinc + RDF for all characters over all the treatments. Interaction effect of biofertilizers with 100% RDF was significant for all characters.

Keywords: sweet corn, bio fertilizers, NFB, PSB, KMB, inorganic fertilizers

Introduction
Sweet corn (*Zea mays* L. saccharata) is a hybridized variety of maize (*Zea mays* L.) also known as sugar corn. Sweet corn is one of the most popular vegetables in the USA, Canada and Australia. It is becoming popular in India and other Asian countries. Sweet corn differs from other corns (field maize, pop corn and ornamental) because the kernels have a high sugar content in the milk on early dough stage. It is consumed in the immature stage of the crop. The kernels of sweet corn taste much sweeter than normal corn, especially at 25-30% maturity. The sweet corn industry is expanding because of increasing domestic consumption, export development and import replacement. It is an attractive crop for producers to grow because the plant grows quickly and it is considered a valuable rotational crop and farming operation can be mechanized. It has a sugary rather than a starchy endosperm and a creamy texture. The low starch level makes the kernel wrinkled rather than plumpy. At harvest, an optimum kernel moisture content of 70 to 74 per cent is required to achieve acceptable frozen cobs. When the moisture content is higher than 74 per cent the cobs are immature and below 70 per cent they lose the sweetness and develop an unpleasant taste and texture. It has a thinner pericarp than the normal corn making it tender. The green cobs are eaten, roasted or boiled. In sweet corn best nutritional quality depends on moisture (72.7%) and total solids (22.3%) comprising of carbohydrate (75- 80 %), protein (13%) and lipids (3.5%) (Rasool *et al.*, 2015) [13].
Among the various factors affecting the growth and yield of sweet corn, nutrient management plays a vital role. It is desired that the soil should have the required nutrients in sufficient quantities and in optimum proportion to meet the requirement of crop. Presently, the chemical fertilizers are considered as the major source of nutrients. However, the escalating cost, coupled with increasing demand of chemical fertilizers and depleting soil health necessitates the safe and efficient use of micro-organisms in crop production. Bio fertilizer is a natural

product carrying living microorganisms derived from the root or cultivated soil. So they don't have any ill effect on soil health and environment. Besides their more important role in atmospheric nitrogen fixation, potassium mobilization and phosphorous solubilisation, these also help in stimulating the plant growth hormones providing better nutrient uptake and increased tolerance towards some environmental stress. A small dose of bio fertilizer is sufficient to produce desirable results because each gram of carrier of biofertilizers contains at least 10 million viable cells of a specific strain (Mazid and Khan 2018) [10]. Hence, Bio fertilizers play an important role in the increasing availability of nutrient elements and helps to growth and yield of sweet corn.

Azotobacter spp. is one of the dominant non-symbiotic nitrogen fixing heterotrophic bacterium in Indian soil. The ability to fix elemental nitrogen is a vital physiological characteristic of *Azotobacter* spp. which is reported to fix 20-60 kg/ha nitrogen in soil annually. *Azotobacter* was the first and is the most common bio fertilizer for some plants such as maize, wheat, sorghum and rice which produces some plant growth promoting metabolites, enzymes and hormones (auxin, cytokinin and gibberelin) in addition to fixing air nitrogen (Forlain *et al.*, 1998) [1].

Phosphate Solubilizing Bacteria (PSB) is a group of beneficial bacteria capable of hydrolyzing organic and inorganic phosphorus from insoluble compounds. Some PSB produce phosphatase like phytase that hydrolyses organic forms of phosphate compounds efficiently. The use of phosphate solubilizing bacteria as inoculants simultaneously increases Phosphorus uptake by the plant and crop yield. Strains from the genera *Pseudomonas, Bacillus* and *Rhizobium* are among the most powerful phosphate solubilizers (Satyaprakash, 2017) [15].

Potash Mobilizing Bacteria (KMB) has great role as for plant growth it is usually abundant in soil. Total Potash Mobilizing Bacteria contents in soil range between 3000 to 100,000 kg/ha in the upper 0.2 m of the soil layer. KMB plays a vital role in the formation of amino acids and proteins from ammonium ions, which are absorbed by roots, from the soil. KMB are also responsible for the transfer of carbohydrates, proteins, etc. from the level to the roots. Potash Mobilizing Bacteria are also known to produce amino acids, vitamins and growth promoting substances like Indole acetic acids and Gibberellins (Ponmurugan and Gopi, 2006) [12].

Application of micronutrient also play significant role in improvement of grain and cob yield of maize. Among micronutrient zinc plays an important role in photosynthesis, nitrogen metabolism and regulates auxin concentration in the plant. The Zn deficiency was found wide spread in Indian soil. Zinc is most crucial amongst the micronutrients that take part in plant growth and development due to its catalytic action in metabolism of almost all crops (Marngar and Dawson, 2017) [9]. Since maize crop is very sensitive to zinc deficiency an application of 20kg zinc/ha is recommended along with the basal dose of fertilizers (Handbook of Agriculture, 2006) [4] The aim of present study is to assess the effect of bio fertilizers with chemical fertilizers and zinc on growth, yield and biochemical parameters of sweet corn (*Zea mays* L. saccharata).

Materials and Methods

This research was carried out during early zaid season 2018, in research field, Department of biological sciences, SHUATS, Allahabad (U.P) Which is located at 25^0 57'N latitude, 87º 19' E longitude 98 m altitude above the mean sea level. The soil of the experimental area was sandy loam having pH; (7.4). The experiments was laid out in Randomized block design with three replications on a gross plot size of field was 15.9 x 4.20 m and net plot size was 12 x 3 m. And the each plot size was of (1 x 1) 1 m with distance of 0.45 m between rows and 0.30 m between plants with in a row. 5 times irrigation, fertilizers application and other cultural practices were followed to raise a sweet corn crop. The treatments included in the experiment were mentioned in table-1.

Table 1: Details of experimented treatments

	Details of treatments
T_0	Control
T_1	RDF (120:60:40)
T_2	NFB (*Azotobacter chroccocum) with* seed inoculation @ 20gm/kg of seed + RDF
T_3	PSB (*Bacillus megaterium*) with seed inoculation @ 20gm/kg of seed + RDF
T_4	KMB (*Frateuria aurantia*) with seed inoculation @ 20gm/kg of seed + RDF
T_5	NFB (*Azotobacter chroccocum)* with soil application @ 3kg/ha + RDF
T_6	PSB (*Bacillus megaterium*) with soil application @ 3kg/ha + RDF
T_7	KMB (*Frateuria aurantia*) with soil application @ 3kg/ha + RDF
T_8	Zinc @ 20kg/ha + RDF
T_9	NFB (*Azotobacter chroccocum)*+ PSB (*Bacillus megaterium*) + KMB (*Frateuria aurantia*) with seed inoculation + Zinc + RDF
T_{10}	NFB (*Azotobacter chroccocum)*+ PSB (*Bacillus megaterium*) + KMB (*Frateuria aurantia*) with soil application + Zinc + RDF
T_{11}	NFB (*Azotobacter chroccocum)* + PSB (*Bacillus megaterium*) + KMB (*Frateuria aurantia*) with seed inoculation + soil application +Zinc + RDF

Sweet corn (*Zea mays* L. Saccharata) variety USM- Sugar gold was sown on 9th February 2018 @ 12kg seed ha^{-1}. Application of biofertilizers as seed inoculation @ 20g/kg of seed before 1hr of sowing and @ 3 kg/ha with 50 kg FYM at the time of land preparation on the base of research plan of work. At the time land preparation while as full dose of phosphorus and potassium and half dose of nitrogen was applied as basal dose while remaining nitrogen was applied in two equal split applications at knee high stage and pre-tasseling stage. The source of N, P and K were Urea, Diammonium phosphate and Muriate of potash respectively. All the cultural operations were performed as per the package of practices of sweet corn.

Seed treatment by different biofertilizers as NFB containing *Azotobacter chroococcum* culture, PSB containing *Bacillus megaterium* and KMB containing *Frateuria aurantia* culture were obtained from market source from yash green land private limited, Teliarganj, Allahabad (U.P). The bacterial slurry of each culture separately and together on the base of different treatments combination was prepared and applied as per procedure mentioned below. (i) 200 g of jaggery was dissolved in 200 ml of water. Jaggery solution as per the volume of seed was prepared. (ii) The culture of biofertilizers was throughly mixed for slurry preparation in above solution. (iii) Seeds were treated with this mixture carefully, so that seed coat was not injured and a uniform coating is made. (iv) Treated seeds were dried under shade on gunny bags and then used for sowing.

The data were recorded from five randomly selected plants which were tagged from penultimate rows of each plot and the average for every parameter was worked out. Days taken to different physiological stages were recorded at various growth stages i.e. days to tasseling and silking stages. Plant height (cm), number of green leaves per plant were recorded at 30 and 60 days after sowing (DAS). Green cob yield with and without husk (kg $plot^{-1}$), green fodder yield (kg $plot^{-1}$), were recorded from 5 cobs taken randomly from each net plot and then converted to kg $plot^{-1}$.

The biochemical parameters such as total chlorophyll contents were estimated by following the methods given by (Arnon, 1949), protein contents were estimated by following the methods given by (Lowry *et al.*, 1951) [8], The total carbohydrate content was estimated by the method by (Hedge and Hofreiter, 1962). The raw data was subjected to appropriate statistical procedure as suggested by Gomez and Gomez (1984) [3].

Results and Discussions

Growth parameters

In general, the growth parameters *viz.*, plant height, number of leaves per plant, days to 50% tasseling and silking; Data related to plant characteristics presented in table-2. Significant difference was recorded among the treatments with respect to maximum plant height 90.58cm at 30 DAS and 237.96cm at 60 DAS and maximum no of leaves 7.93 at 30 DAS and 14.53 at 60 DAS was recorded in the treatment having T_{11} compared to T_0 (Control) where was found minimum plant height 48.500 at 30 DAS and 143.08 cm at 60 DAS and also found minimum no of leaves 5.86 at 30 DAS and 8.40 at 60 DAS. The increase in growth of sweet corn could be attributed to the enhanced nutrient use efficiency in the presence of biofertilizer. *Azotobacter* fixes the atmospheric nitrogen and PSB mobilize phosphorous making these elements available for plant growth and development. *Azotobacter* secretes certain growth promoting substances like auxin, gibberellins, vitamins and organic acids which improve the growth. Whereas, PSB has ability to fix higher dose of phosphorous which stimulate root growth and enhances the absorption of nutrients thus resulting vigorous growth. The results are in agreement with the findings of Rathi, *et al*. (2005) [14] and Kumar *et al*. (2006) [7]. The significantly minimum no of days 52.56 to 50% tasseling and minimum no of days 56.66 to 50 % silking 52.56 was recorded in the treatment having T_{11} respectively. It might be due to inoculation of *Azotobacter*, PSB and KMB which increased availability of macro and micro nutrients and improved hormonal activities in plant ultimately affect flowering characters Syamal *et al*. (2006) [19]. They produce growth promoting substances which are beneficial to improved flowering characters. These findings are in close conformity with the findings of Kumar *et al.* (2006) [7] and Rasool *et al*. (2015) [13].

Significantly maximum number of panicles per plant was also observed with the application of *Azotobacter* + PSB + KMB. It might be due to the fact the bio-fertilizers produce the growth promoting substance and other acids like acetic, formic, proponic, lactic, glyconic, fumaric and succinic which were positively correlated with growth, flowering and yield. It has also been reported by Kumar *et al.* (2006) [7].

Yield attributes

Effect of different treatments of biofertilizers with 100% RDF and zinc on yield attributes of sweet corn are observed in table-3. That difference between treatments were significant with regard to all the green cob and green fodder characters of sweet corn. Maximum number of cob/plant 1.66 was recorded in T_{11} while minimum number of cob 0.60 was found in treatment T_0. Significantly maximum number of panicles per plant was also observed with the application of *Azotobacter* + PSB + KMB. It might be due to the fact the bio-fertilizers produce the growth promoting substance and other acids like acetic, formic, proponic, lactic, glyconic, fumaric and succinic which were positively correlated with growth, flowering and yield. It has also been reported by Kumar *et al.* (2006) [7]. However, highest cob weight [285.90gm (with husk) and 179.70gm (without husk)] was recorded in T11 and minimum [125.30gm (with husk) and 88.03gm (without husk)] in T_0. Cob length of sweet corn 27.80cm with husk and 18.86cm without husk, and cob girth of sweet corn 15.13 cm with husk and 12.96 cm without husk was also significantly maximum with the same treatment T_{11}. These results are in accordance with the work of (Shaharoona *et al.* 2006) who reported such increase in yield attributes of maize due to application of biofetrilizers and showed present investigation. Yield per plot (kg) of sweet corn 4.28 kg of cob with husk and 4.54 kg of green fodder was the maximum in the treatment T_{11}, while significantly minimum cob yield 0.69 kg $plot^{-1}$ with husk and green fodder 1.84 kg $plot^{-1}$ was recorded in T_0. It is clear from the above result, among all the treatment T_{11} was found the best. Jarak *et al.* (2011) arrived at similar conclusions concerning the use of free-living and associative nitrogen fixing bacteria in maize production. Shaukat *et al*. (2006) and Egamberdiyeva (2007) stated that biofertilizers increase maize yield by stimulating processes such as seed germination, resistance of seedlings to stress conditions, nitrogen fixation and production of phytohormone. It significantly increased the yield and yield attributes when applied with biofertilizers with seed inoculation @ 20g kg-1 seed and @ 3kg/ ha with soil application. The biofertilizers like *Azotobacter* and PSB were also found to fix atmospheric nitrogen into available nitrogen to the plants Okon *et al*. (1981). Hence the soil application and seed treatment with biofertilizers responsible for supply of nutrient to increase in the plant growth and yield parameters.

Biochemical parameter

The present study, Application of treatment T_{11} showed superior performance over other treatments recording significantly higher values for all the biochemical parameters presented in table-4 *viz*., total chlorophyll content 4.02 mg g^{-1} of fresh weight which was lowest 2.33 mg/g of fresh weight in T_0, Protein content 11.54% which was lowest 6.81% in T_0, Carbohydrates content 78.61% which was lowest 57.15% in T_0.

Maximum amount of chlorophyll pigment may show an efficient rate of photosynthesis. Koide (1993) [6] reported that using biofertilizers increases leaf chlorophyll content and can positively affect rate of photosynthesis. Significantly variation on protein and carbohydrates content was noticed due to the application of inorganic fertilizers with different biofertilizers are presented investigation. The above held report was in accordance with the previous result of Sudhalakshmi *et.al.* (2011) [18].

Conclusion

It can be concluded from present investigation that the effect of biofertilizers with chemical fertilizers and zinc on growth, yield and biochemical parameters of sweet corn (*Zea mays* L. *saccharata*) result shown significantly higher in T_{11} [NFB (*Azotobacter chroccocum)* + PSB (*Bacillus megaterium*) + KMB (*Frateuria aurantia*) with seed inoculation + soil application + Zinc + 100% RDF].

Table 2: Effect of biofertilizers with chemical fertilizers and zinc on growth parameters of sweet corn

Treatments	**Plant hieght (cm)**		**No. of leaves**		**Days to tasseling**	**Days to silking**
	30 DAS	**60 DAS**	**30 DAS**	**60 DAS**	**No. of Days**	**No. of Days**
T_0	48.50	143.08	5.87	8.40	68.33	71.66
T_1	85.00	205.19	7.13	12.87	59.00	62.66
T_2	88.71	225.23	7.67	13.67	56.00	59.66
T_3	85.83	209.98	7.33	13.40	58.00	61.33
T_4	85.91	212.49	7.33	13.93	57.00	60.00
T_5	89.46	227.65	7.67	13.27	55.33	59.00
T_6	87.53	222.64	7.60	13.07	57.00	60.33
T_7	86.90	226.52	7.47	13.87	56.00	59.33
T_8	85.87	206.69	7.23	13.53	58.67	62.33
T_9	90.21	232.76	7.67	14.00	54.67	58.33
T_{10}	90.27	233.41	7.93	14.07	53.67	57.33
T_{11}	90.59	237.96	7.93	14.53	52.67	56.33
F – test	S	S	S	S	S	S
C.D. (0.05)	1.83	5.44	o.88	0.54	1.5	1.86
S. Ed. (±)	0.88	2.62	o.42	0.24	0.72	0.89

Table 3: Effect of biofertilizers with chemical fertilizers and zinc on yield attributes of sweet corn

Treatments	**No. of cob plant^{-1}**	**Cob Length (cm)**		**Cob Girth (cm)**		**Weight (g cob^{-1})**		**Cob yield with husk**	**Green fodder yield**
		With husk	**Without husk**	**With husk**	**Without husk**	**With husk**	**Without husk**	**(kg plot^{-1})**	**(kg plot^{-1})**
T_0	0.60	16.75	10.51	8.60	5.40	125.30	88.03	0.69	1.84
T_1	1.06	22.76	16.47	11.73	9.26	207.66	140.43	1.99	3.65
T_2	1.33	25.82	17.36	13.03	10.00	236.76	156.30	2.83	4.16
T_3	1.20	23.92	16.67	12.30	9.26	229.13	151.00	2.47	4.00
T_4	1.26	24.60	17.10	13.60	10.43	245.00	163.36	2.79	4.16
T_5	1.46	26.11	17.27	13.16	10.10	246.76	164.26	3.25	4.18
T_6	1.26	24.54	17.50	12.73	10.00	233.90	151.46	2.66	3.94
T_7	1.40	25.70	17.29	14.03	11.76	249.16	166.63	3.14	4.17
T_8	1.33	24.26	16.93	12.20	9.63	220.00	146.60	2.64	3.94
T_9	1.46	26.50	17.92	14.13	11.26	256.56	167.93	3.38	4.34
T_{10}	1.60	27.10	18.18	14.33	11.83	276.70	170.63	3.98	4.44
T_{11}	1.66	27.80	18.86	15.13	12.96	285.90	179.70	4.28	4.54
F – test	S	S	S	S	S	S	S	S	S
C.D. (0.05)	0.192	0.78	0.62	0.68	0.93	10.25	6.56	0.37	o.10
S. Ed. (±)	0.109	0.37	0.30	0.32	0.45	4.94	3.16	0.16	0.06

Table 4: Effect of biofertilizers with chemical fertilizers and zinc on biochemical parameters of sweet corn

Treatments	**Total chlorophyll content (mg g^{-1} FW)**	**Protein content (%)**	**Carbohydrates content (%)**
T_0	2.333	6.81	57.150
T_1	2.970	9.11	68.953
T_2	3.653	10.21	74.010
T_3	3.500	9.56	72.133
T_4	3.636	9.98	73.083
T_5	3.700	10.76	75.330
T_6	3.580	9.93	72.593
T_7	3.643	10.29	73.760
T_8	3.413	9.81	71.973
T_9	3.723	10.95	76.146
T_{10}	3.823	11.29	76.500
T_{11}	4.020	11.54	78.610
F – test	S	S	S
C.D. (0.05)	0.09	0.40	2.44
S. Ed. (±)	0.04	0.19	1.17

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